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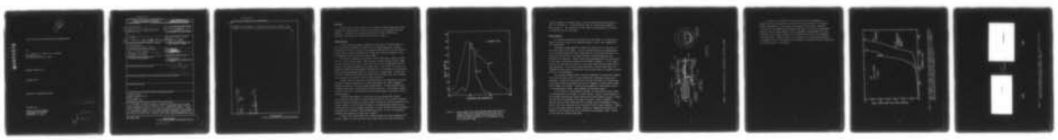

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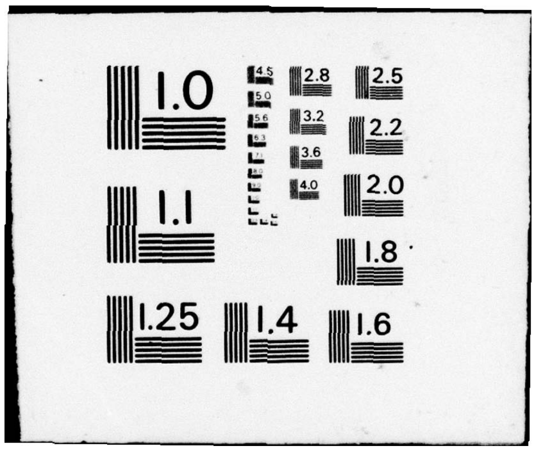
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INJECTION LASER FOR HIGH-DATA-RATE COMMUNICATION

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The goal is the development of methods of coupling as much power from an injection laser as possible into a single-mode fiber, with the fiber permanently bonded to the laser in a protective package. Study of the factors controlling laser beam patterns continues. Some evidence of dimensional changes in the epoxy fiber-laser bonding has been seen; new epoxy is being tried. Several laser-fiber sealed packages have been

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assembled for evaluation. Power levels of about 1 mW have been coupled into the fiber, and long-term stability is being studied.

OBJECTIVE

The objective of this contract is to develop a stable single-mode fiber assembly for coupling power from a cw laser diode into a permanent pig-tail assembly. Included in this program are studies of laser diode device parameters affecting the coupling efficiency into fibers.

FIBER COUPLING

In this reporting period, progress has been made in isolating many of the factors which degrade the stability of the single-mode laser assembly. The greatest difficulty involves the thermally induced shifts in the structure in the course of laser operation which change the critical alignment of the 8-μm-diameter fiber core with the laser diode.

The required dimensional tolerances on the laser-fiber system are shown in Fig. 1 for a typical laser. Here the power coupled through a short length of fiber is seen to fall off as the center of the core is displaced from the center of the emitting region on the laser facet. The fall-off is seen to be especially sharp with displacements perpendicular to the plane of the junction: even a ± 1-μm displacement leads to a reduction in coupled power of about 20%, or 1 dB. (With the 25-μm-wide electrical contact stripes used, the tolerances in the plane of the junction are 3-4 times as great.)

Thermal shifts in the laser, and especially in the thermoelectric cooler elements, during cw operation can prevent maintenance of proper alignment during the setting of the fiber-laser bonding epoxy. We have therefore used alignment under short, low-duty-cycle pulsed conditions. This greatly reduces the heat delivered to the system and has permitted greater positional control during bonding.

Continued measurements on laser-fiber systems bonded with Varian's Torr-Seal give indications of small dimensional shifts over a period of months. We have therefore switched to another epoxy, Metalset A4, made by Smooth-On, Inc. It may, however, turn out that all epoxies are dimensionally unstable and we will be forced to other bonding techniques. We have therefore given preliminary consideration to possible solder-bonding approaches. So far, no insuperable problems have appeared in using such a method.

Several laser single-mode fiber sealed packages have been assembled and tested. Powers of over a milliwatt (at rather high drive levels) have been

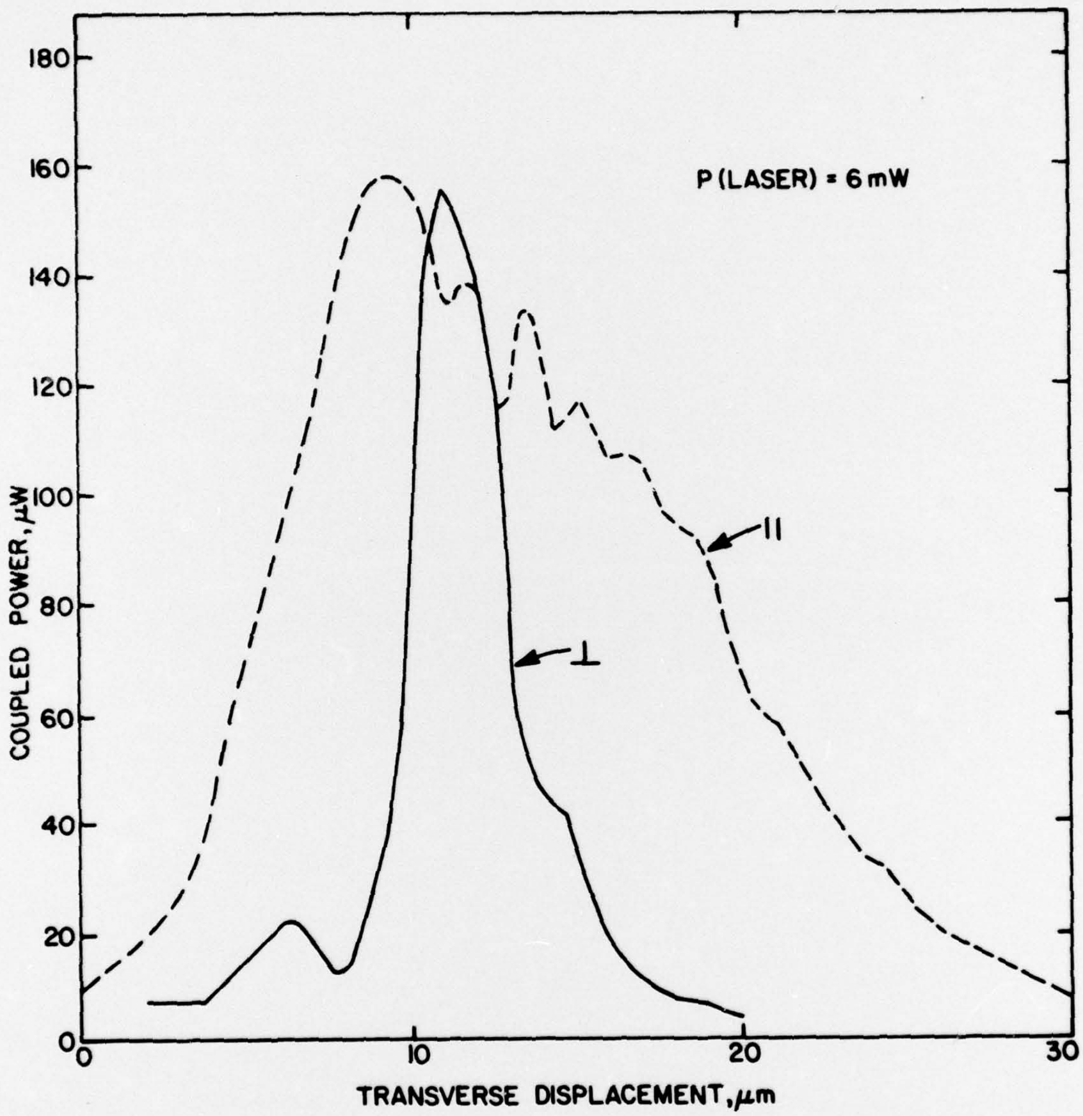

Figure 1. Power coupled from laser through single-mode fiber as cleaved fiber end is displaced from its position of otpimum coupling by moving it perpendicular to the fiber axis either parallel (||) or perpendicular (⊥) to the junction plane.

coupled through the attached fibers. Two such units have been delivered to NELC for evaluation. A cross-sectional view of a laser-fiber package is shown in Fig. 2. The cleaved end of the fiber is mounted about 25 μm from the emitting facet of the laser.

DEVICE STUDIES

To couple as much power as possible into the fiber, it is desirable to operate the laser diode at the maximum possible current level commensurate with reliability.

Coupling strategy depends on whether the fiber end is in the near- or far-field region of the laser. For the transverse direction (perpendicular to the junction plane) the fiber, being about 25 μm from the laser facet, is clearly in the far field, and lasers having narrow beam angles in this direction are desirable. (Other factors than coupling enter into this choice; we feel that a beam angle of about 35°-40° FWHM is optimal.) In the lateral plane of the junction, the fiber is in the near field, and beam angles are of less importance. We have been using lasers with a 25-μm stripe width, but comparable optical power coupling with 13-μm stripe lasers is probably possible. This will be investigated.

Our previous Progress Report detailed experiments concerned with changes in the lateral mode profile of laser diodes with increasing current above threshold. During this reporting period we have succeeded in isolating some of the major effects associated with current changes in stripe contact lasers. These changes are related to either basic parameters of the specific device or to metallurgical flaws. Some examples are described below.

In the course of testing many cw diodes, we have found two basic types of nonlinearities in the power vs current curves. Figure 3 shows examples of two extremes observed with lasers having 13-μm stripe widths, and Fig. 4 shows the near-field micrographs of the same two lasers. Diode A exhibits a behavior which we have identified with a change from the fundamental lateral mode to the first order one in the vicinity of 8 mW of power emission. Diode B, on the other hand, exhibits behavior related to filamentary emission due to defects in the junction and is not susceptible to systematic study. Lasers of this type are normally discarded.

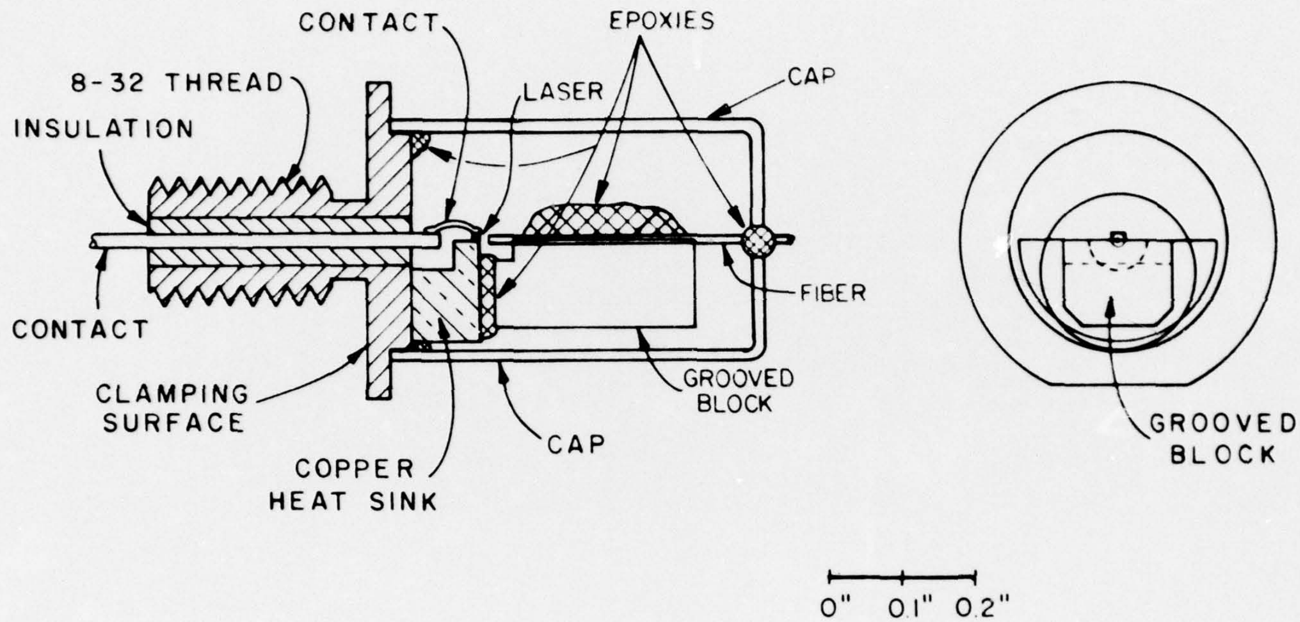

Figure 2. Cross-sectional view of a developmental laser-fiber package.

The change in the dominant, lateral mode from the fundamental to a higher order one is reflected in the far-field in the plane of the junction. Indeed, measurements of the angular distribution can be used to determine the power in the fundamental and higher order mode. Our initial measurements indicate that the power emission in the fundamental lateral mode in the low threshold, narrow lasers tested so far can saturate at about 20 mW (emission from both sides). However, there is no evidence so far that this represents a fundamental limit, and studies are in progress to establish factors controlling the lateral modes in our devices.

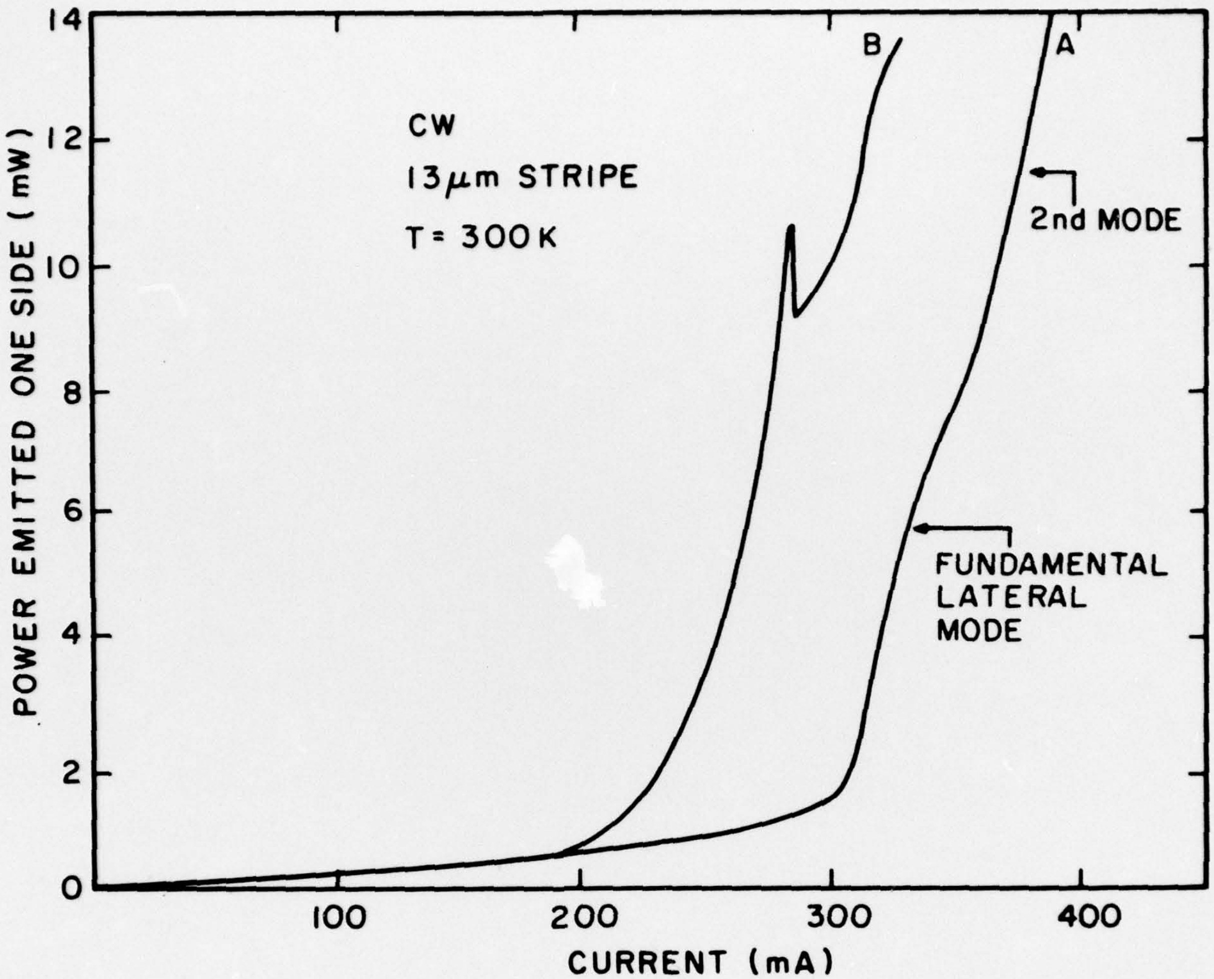

Figure 3. Power emission vs current of two cw laser diodes operating at room temperature. Laser A exhibits a change from dominant fundamental lateral to the higher order mode. Laser B contains a defect in the junction giving rise to filamentary behavior as shown in the near-field micrographs of Fig. 4.

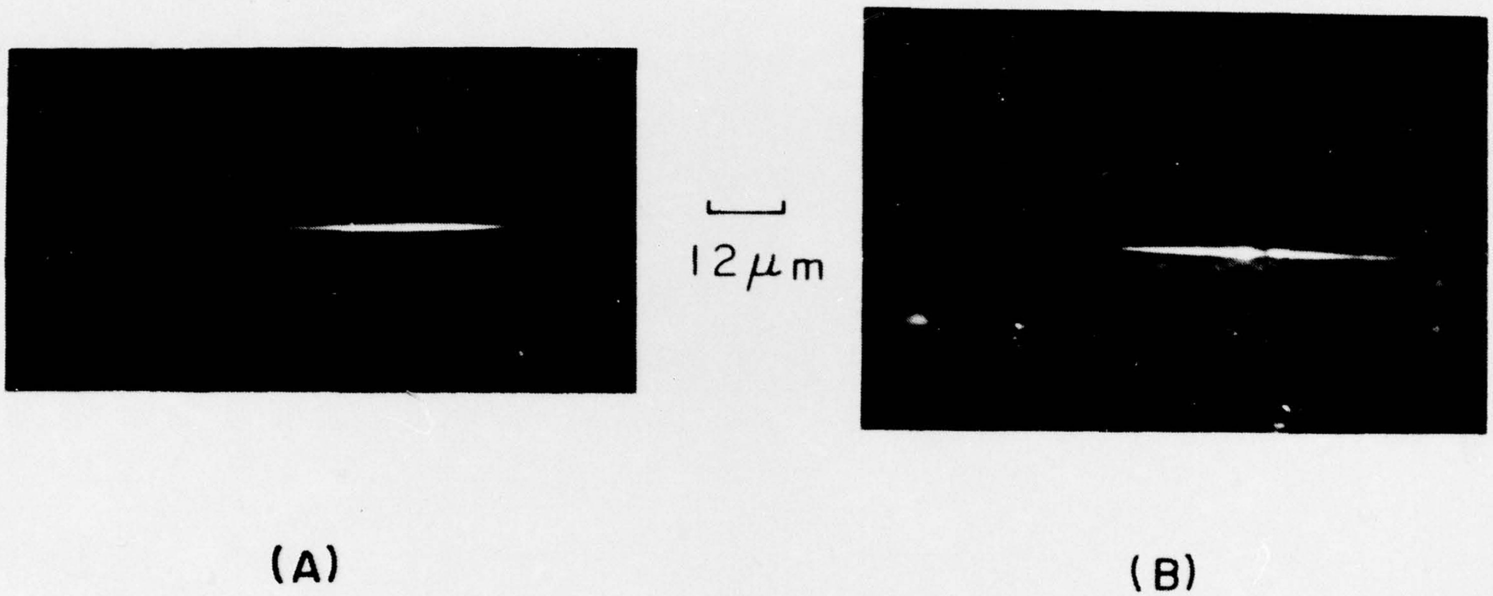

Figure 4. Near-field micrographs of the two lasers of Fig. 3 showing a good quality device A and one with filamentary behavior, device B.